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NRL Report No. 4728
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PROJECT VANGUARD REPORT NO. 3
PROGRESS THROUGH MARCH 15, 1956

[UNCLASSIFIED TITLE]

Project Vanguard Staff

March 29, 1956

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Previous Project Vanguard Reports

"P.V.R. No. 1, Plans, Procedures, and Progress" by the Project Vanguard Staff, NRL Report 4700 (Secret), January 13, 1956

"P.V.R. No. 2, Report of Progress" by Project Vanguard Staff, NRL Report 4717 (Confidential), March 7, 1956

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ABSTRACT
[Confidential]

A preliminary support and data acquisition plan for Project Vanguard has been prepared by AFMTC, and a completed plan for the test program is expected in the near future. The Minitrack station originally planned for Barbuda will be considered as a part of the range instrumentation facilities. However, a scheduled site survey trip to Antigua is expected to result in the location of the station on that island rather than Barbuda for logistic reasons. Minitrack equipment may also be installed on two regular range stations in the island chain.

Reduction of the third-stage length to 60 inches has reduced the over-all length of the launching vehicle to 71 feet 4 inches, and substitution of magnesium alloy for aluminum alloy in certain areas has reduced the weight of the vehicle by 39 pounds in the first stage and 14 pounds in the second stage. A stainless steel "spaghetti" chamber for the second stage is being fabricated, and a program has been initiated for a similar aluminum chamber which, if satisfactory, will result in a substantial weight saving. A new subsonic wind-tunnel test will be made on the Vanguard configuration.

A trajectory study has been formulated to investigate autopilot stability margins on a finless missile. Trajectories for range safety and tracking planning have been computed on the basis of estimated weight and performance parameters.

Some prototype thrust chambers for the first-stage powerplant have been fired for 120 seconds at rated mixture ratio, and although there were no signs of burnout on the walls, several instances of face burnout occurred on the periphery of the injector. Completed mockups of the first- and second-stage powerplants have been delivered.

Schedules for delivery and installation of launching vehicle telemetering equipment have been formulated. Development of ppm/am ground stations is behind schedule and the contractor's staff has been increased in order to meet the schedule. Specifications for fm/fm transmitters have been released for procurement initiation, and bids for ppm/am and pwm/fm transmitters have been received. Proposals have been requested from several contractors for a minimum-weight command receiver for the launching vehicle.

Three different types of satellite are being designed, and the final choice of the type to be used will be made at a future date; a study of fabrication methods for satellite assemblies is under way. A schedule has been agreed upon for the development of scientific instrumentation for the satellites, and a tentative environmental test program has been formulated on the basis of estimated environmental conditions. Studies are being made of satellite telemetry coding systems; data storage, readout, and ground recording systems; and a meteor collision detection system.

The request for bids to provide computational facilities has been released and proposals will be accepted by ONR until 15 April 1956; a decision will be made immediately after that date.

PROBLEM STATUS

This is an interim report; work on the problem is continuing.

AUTHORIZATION

NRL Problem A02-18

Manuscript submitted March 26, 1956

PROJECT VANGUARD REPORT NO. 2
PROGRESS THROUGH MARCH 15, 1956
[UNCLASSIFIED TITLE]

INTRODUCTION

This report is intended as a general summary of the progress on Project Vanguard through 15 March 1956. Hence, minor phases of the work are not discussed to any great extent and technical detail is kept to a minimum. It is hoped that the information here provided will be of value to administrative and liaison personnel in coordinating and planning their activities, and as a guide to the current status of the project. Material of a more technical nature will be published from time to time in separate reports which will be announced in the subsequent monthly progress report.

COORDINATION WITH OTHER SERVICES

Army

Tracking

The Army has accepted the responsibility for establishing, operating, and maintaining the satellite tracking network, including communications, provided funds are made available. The tracking station near Washington, D. C. and the one to be located on the Island of Barbuda* are excluded from this responsibility.

A ground reconnaissance trip is scheduled to select tracking station sites and obtain an accurate scope of work. On 5 March 1956, NRL met with the Corps of Engineers and the Signal Corps to reappraise the NRL requirements and review the Army program to meet them. The meeting resulted in a simplified program which should reduce the cost to well below the initial estimates.

Construction

The Army District Engineers are directing the construction of the VANGUARD launching facility and assembly hangar at AFMTC. In addition, they have assumed the responsibility for disassembling at the White Sands Proving Ground, transporting, and re-erecting at AFMTC, the Viking gentry crane for use by the Vanguard Program.

Technical Program

Crystal-controlled receivers and DOVAP transponders are being procured from the Ballistics Research Laboratory at Aberdeen Proving Ground. Both the Diamond Ordnance Fuze Laboratory and the Picatinny Arsenal are being contacted for development of a time delay and a separation mechanism. The Diamond Ordnance Fuze Laboratory is developing an antenna to be extended by an explosive charge for early test. Models

*As will subsequently be pointed out, it has been decided to locate this station on Antigua rather than Barbuda.

of the Vanguard vehicle have been tested in the Ballistics Research Laboratory wind tunnel at Aberdeen Proving Ground by GLMCO and more are planned. Early in the program both SCEL and BRL submitted proposals to undertake satellite tracking and scientific instrumentation. A considerable number of parts and equipments from the Army Hermes program have been made available to the Project Vanguard to assist in the development of the first-stage engine. Discussions have been had with the Office of the Chief of Ordnance concerning types of vans which may be suitable for use with project instrumentation.

Technical Program

Preliminary discussions have been conducted between NRL and the Army Signal Corps concerning the use of an FPS-16(XN-2) radar at AFMTC. The Ballistics Research Laboratory has been studying the problem of zero-vertical-velocity determination in the trajectory.

Scientific Program

Contact is being maintained between Project Vanguard and the Army Map Service to consider geodetic aspects of the program. The AMS has expressed interest in the simplified Minitrack system.

Air Force

Test Range Facilities

The Air Force Missile Test Center has prepared a preliminary support and data acquisition plan for Project Vanguard. Conferences are being held to finalize the preliminary requirements and support plans into a completed test program.

Technical Program

Technical liaison is being maintained through the Air Force program officer with the following Air Force Agencies:

1. Deputy Chief of Staff (Development), Hq., USAF

2. Assistant Chief of Staff for Guided Missiles, Hq., USAF

3. Western Development Division, USAF Representative, Hq. Air Research and Development Command, Intelligence, Reconnaissance, and Supporting Systems Division

Scientific Program

The Cambridge Research Center has submitted four proposals for scientific experiments to the National Science Foundation.

LOGISTIC SUPPORT

Test Range Facilities

The status of the various test range facilities required by the Vanguard test program is as follows:

Administrative Facilities

The AFMTC Vanguard Project Officer, Cdr. H. W. Calhoun, is being provided office space and administrative support at PAFB by the Air Force. Space for additional personnel will be made available when required.

Assembly Hangar Space

Plans for the construction of a new hangar with space for Vanguard is proceeding on schedule. Interim space in Hangar C, starting (July 1956), has been requested. Although this has not yet been formally approved, informal information indicates that the space will be made available as requested.

Range Instrumentation

The technical status of range instrumentation is discussed in other portions of this report. In terms of facilities it has been decided to consider the Minitrack station originally scheduled for installation on the island of Barbuda as meeting part of the range instrumentation requirement. This station must perform the important function of measuring third-stage performance during the test phase in addition to its function of measuring the initial satellite orbital conditions during a mission launch.

Preliminary contacts by AFMTC with the British Governor on the island of Antigua, who also has jurisdiction over Barbuda, led to the strong suggestion that Vanguard explore the possibilities of locating the Minitrack station on Antigua rather than Barbuda. This suggestion was made because of the difficult logistic problems that would have to be solved in Barbuda is used, as against those to be encountered on Antigua. A thorough study was made of the best trajectory data available, the range limitations of the telemetry equipment, the launching azimuth limitations imposed by range safety considerations, and finally, the detection range capability of the Minitrack equipment itself. From this study it was concluded that the Antigua location will be acceptable. A site survey group is scheduled to depart Patrick Air Force Base on 20 March 1956 to make a detailed cost and construction estimate for this site.

In addition to the Minitrack station at Antigua, two regular range stations are now being considered for additional instrumentation with Minitrack equipment. Present plans indicate that the station on Grand Turk Island and the one on either San Salvador or Mayaguana should be so equipped.

Launching Facilities

An architectural and engineering conference originally scheduled for 15 March 1956 was held in Miami on 9 March to review the detailed design plans for the Vanguard launching facility. Agreement was obtained on all design items. The A&E contractor now estimates that the detailed design work can be completed by about 1 April 1956 rather than 1 May as originally scheduled.

The Army District Engineers (Jacksonville District) have assumed the responsibility for insuring the operational readiness of the Viking gantry crane at AFMTC by 15 October 1956. Since the construction of the launching facility is also under the supervision of the Army District Engineers, the necessary coordination between the gantry crane contractor and the facility construction contractor can be readily effected; hence the date of 15 October instead of 15 September is considered satisfactory.

The current planning and construction control dates are given below:

Completion of design criteria and topographical survey of site (completed on schedule)	15 February 1956
Final review of detailed design plans (completed 9 March 1956)	15 March 1956
Completion of detailed design; negotiations with selected construction contractors to start (completion of detailed design now estimated 1 April 1956)	1 May 1956
Actual construction to start	15 May 1956
Joint occupancy of blockhouse and pad by contractor and Vanguard engineers	15 August 1956
Operational occupancy of blockhouse and pad by Vanguard engineers; gantry crane to be operational	15 October 1956
Launching of first vehicle (Viking 13) (erroneously given in Project Vanguard Report No. 2 as 20 November 1956)	29 November 1956
Permanent water installation to be available for use in conducting static firing tests (adequate temporary water supply can be made available by 1 November 1956 or earlier if needed)	1 December 1956

Tracking Network

The Army is proceeding with the initial planning steps towards assuming responsibility for establishing, operating, and maintaining the Minitrack system for satellite tracking. The results of the preliminary site survey, conducted by Inter-American Geodetic Survey personnel in the particular areas, have been very encouraging in that the Minitrack requirements can be met without incurring undue construction costs. The final details on cost estimates cannot be provided until the Minitrack site selection survey party has completed its work.

The State Department has advised the various South American embassies of our intent in establishing the Minitrack system. At this writing, response from the individual countries has not been received. Barring unforeseen delays, the site selection survey party should be at the IAGS Headquarters in Panama by 26 March 1956 to start the detailed site selection. The final site selection, with cost estimates for site acquisition, construction, operation, and maintenance during the IGY, should be ready by the early part of May 1956.

The Washington area Minitrack test site, known as the Blossom Point Station, is in the final stages of administrative approval prior to the actual commencement of

construction. As a result of several administrative oversights the construction of this station, which must be in operation by 1 June 1956, is several weeks behind schedule.

THE LAUNCHING VEHICLE

Configuration and Design

The following changes have been made in the Vanguard vehicle configuration:

(1) The first-stage cable and tubing conduits were made external after an aerodynamic study indicated that roll moment due to side winds could be adequately reacted.

(2) The over-all length was reduced to 71 feet 4 inches by the use of a third stage rocket 18 inches in diameter and 60 inches long.

As a result of structural weight and optimization studies, magnesium alloy will be used (1) in the tail section, between the tanks and forward of the lox tank in the first stage, and (2) in the aft skirt and forward of the tank area in the second stage. The estimated weight saving resulting from the use of magnesium alloy instead of aluminum alloy in these areas is 39 pounds in the first stage and 14 pounds in the second stage. In order to assure an effective weight optimization program, the empty-weight goals given in Table 1 have been established.

TABLE 1
Weight Optimization Status and Goals

Stage	Specification Weight (lb)	Current Weight (lb)	Desired Weight (lb)
First	1782	1656	1565
Second	973	955	865
Third	89	89	89

Destruction tests have been established for the following parts of the first stage:

1. Engine mount
2. Tail section
3. Fuel and lox tanks
4. Structure between tanks
5. Structure forward of lox tank
6. Fuel and lox tank longitudinal spaces

Vehicle Specifications

Accord has been reached with the Glenn L. Martin Company on the content of the Vanguard launching vehicle design specification (NRL 4100-1) and the launching vehicle antenna specification (NRL 4100-2). Upon the basis of these specifications the Glenn L. Martin Company is submitting a proposal for its effort in the Vanguard program.

The following Glenn L. Martin specifications have been approved by NRL:

GLM No. 924, Development specifications for liquid-propellant rocket engine for first stage of Vanguard launching vehicle

GLM No. 925, Development specifications for liquid-propellant rocket engine package for second stage of Vanguard launching vehicle

GLM No. 926, Specification for solid-propellant rocket motor for third stage of Vanguard launching vehicle

GLM No. 1064, Development specification for three-axis gyro reference for Vanguard launching vehicle

GLM No. 1082, Design data requirements for Vanguard launching system

The following Glenn L. Martin specifications have been completed and submitted to NRL for review:

GLM No. 1123, Technical data requirements for solid-propellant rocket motor for Vanguard launching vehicle

GLM No. 1126, Specification for static and flight firing structure for the Vanguard launching vehicle

The following Glenn L. Martin specifications are in preparation or revision:

GLM No. 1125, Subsystem specification for Vanguard guidance and control

GLM No. 1130, Development specification for solid-propellant rocket stabilization and retro-motors for Vanguard launching vehicle

GLM No. 1131, Technical data requirements for solid-propellant rocket stabilization and retro-motor for Vanguard launching vehicle

Contracts have been negotiated with the Allegany Ballistics Laboratory and with the Grand Central Rocket Company for parallel developments of third-stage solid-propellant motors through the development and qualification test stages.

Plans have been completed for a vertical assembly and for checkout tooling to be located adjacent to the Martin factory for the purpose of performing complete system checkouts and dynamic tests of assembled vehicles before they leave the factory. Approved also were plans and a contract for the construction of test facilities near the GLM plant for the performance of hazardous developmental tasks such as passivation, the hot testing of control jets, and dynamic tests which involve the use of propellants.

Aerodynamics

A trajectory study has been formulated to investigate autopilot stability margins on a finless missile. The topics to be considered are: the limitations on launching a vehicle of low thrust-to-gross-weight ratio, the control program necessary to achieve the required trajectory, the range of maximum air loads, the maximum gyro error and gimbal deflections to be experienced, the effects of various tolerances, and the dynamical characteristics during staging. This study, which has been programmed for solution on the IBM 701, is broken into four problems: (1) launch phase, (2) first-stage program phase, (3) second-stage program phase, and (4) separation of the first and second stages.

Trajectories have been computed for the test vehicles and for the satellite vehicles on the basis of estimated weight and performance parameters. These preliminary trajectories are for the purpose of range safety and tracking instrumentation planning. A six-degree-of-freedom trajectory study, embodying a complete controls loop and assuming the earth to be a rotating oblate spheroid, has been formulated.

Plans have been completed for a new subsonic wind-tunnel test on the Vanguard vehicle configuration.

Propulsion

First Stage

The General Electric Company has begun test firings on prototype thrust chambers of the first-stage powerplant. No full-duration full-thrust runs have been made, although some chambers have been run for 120 seconds at rated mixture ratio. The silicon deposit was found to work reasonably well on the chamber walls and so far no signs of incipient burnout have been noted. Several instances of face burnout have occurred on the periphery of the injector, however. Changes in the fuel flow pattern are being considered. A completed mockup of the first-stage powerplant (Fig. 1) has been delivered.

Discussions are continuing with GE, NACA, WADC and others on the oxidizer improvement (lox-fluorine) program. A review of a proposed investigational program is underway.

Second Stage

Drawings of experimental and prototype square-grid injector assemblies have been released for fabrication, and one-on-one impinging stream injectors are still in analysis. The firing of a test injector is scheduled for early March. Preliminary heat-transfer investigations have been concluded, and experimental combustion and stability studies are being continued. A stainless steel "spaghetti" chamber is presently being fabricated and a parallel program for an aluminum "spaghetti" chamber has been initiated; if this aluminum chamber proves satisfactory, a substantial decrease in weight will be realized.

The design of fuel and oxidizer propellant valves has been completed and fabrication has been initiated. The procurement of standard check valves, pilot valves, pressure switches, burst diaphragms, etc., has also been initiated. Layouts of the propellant lines are now complete, and the analysis and design of tankage is continuing. A completed mockup of the second-stage propulsion system (Fig. 2) has been delivered to the prime contractor.

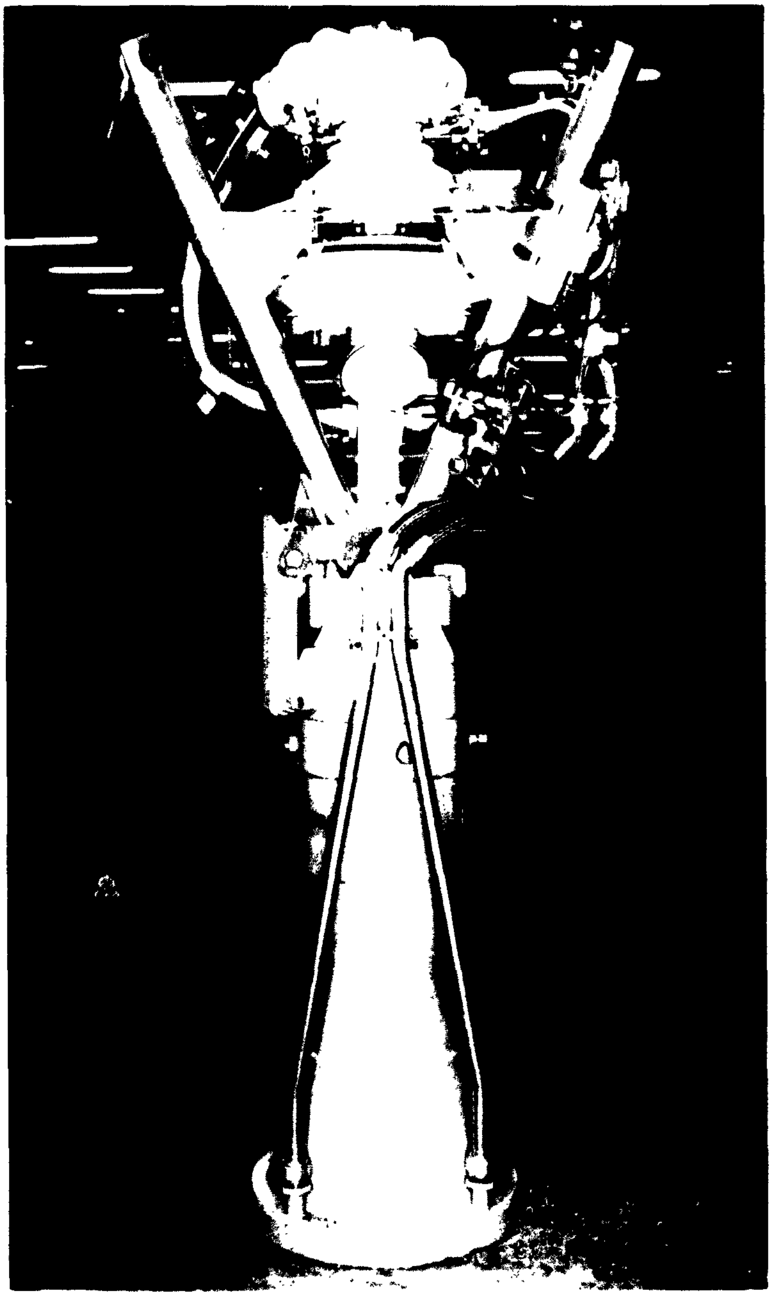

Fig. 1 - Mockup of first-stage powerplant

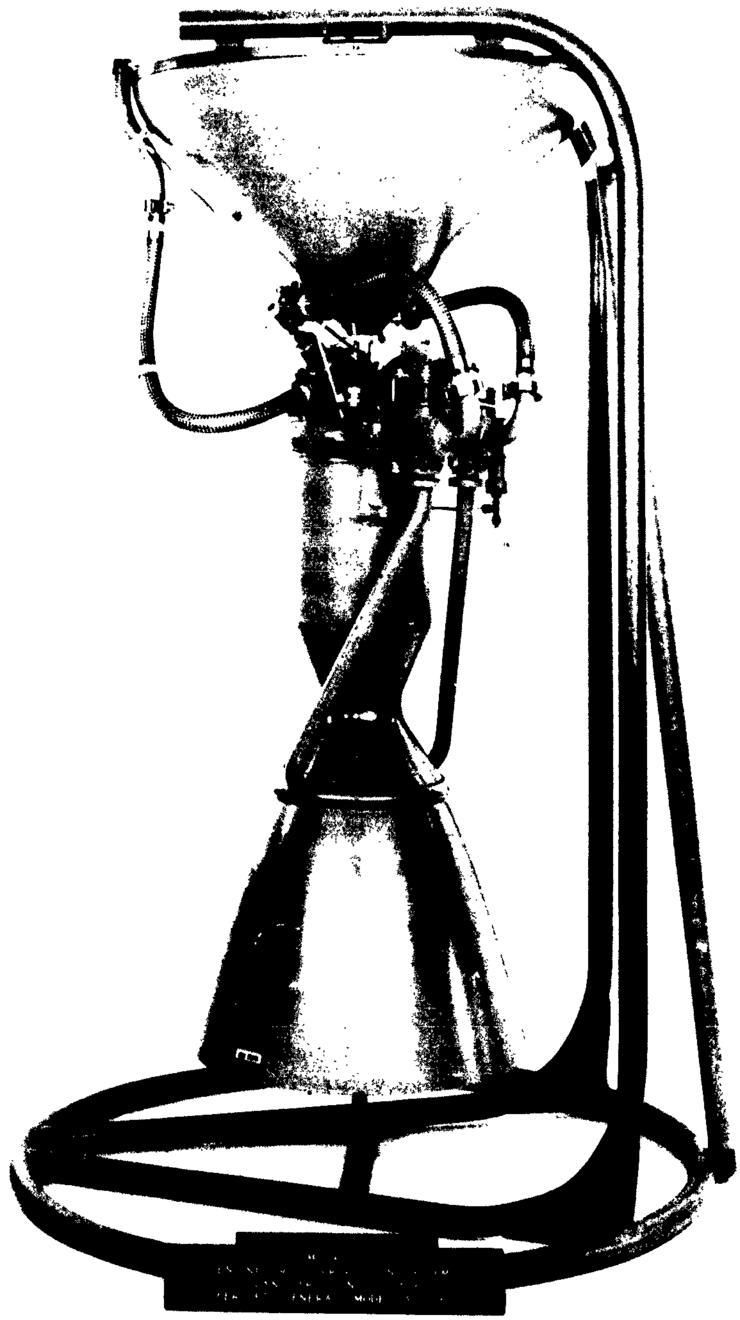

Fig. 2 - Mockup of second-stage powerplant

It has been agreed to consider operation of the system with cooled acid; by this means the performance of the motor can be brought up to required levels. Regenerative cooling will be improved, and if tests show it to be satisfactory, type 3 RFNA will be used as the oxidizer. This substance has a higher density and density impulse than WFNA.

Third Stage

Specification GLM No. 926 has been modified in such a manner as to make it acceptable to both the Allegany Ballistic Laboratory and the Grand Central Rocket Company, and developmental work has been initiated by both suppliers.

Flight Control

Preliminary analysis of the instrumentation required to obtain the launching vehicle trajectory is in process. One approach under consideration is the use of a timed pitch-over program consisting of four constant values of pitching rate. This program provides an approximate zero-normal-force trajectory during powered flight and properly orients the vehicle attitude in pitch during post-cutoff flight prior to the firing of the third stage. Determination of the time at which the vehicle reaches second-stage apogee is based on an empirical linear relationship with respect to vehicle velocity at second-stage burnout. An integrating accelerometer combined with a timing mechanism would be required to establish this relationship.

Studies of the vehicle attitude jet controllers have been made with preliminary values for lead-network parameters. The steady static ratio of jet-on time to period of jet actuation is 1:70 for the second stage pitch-yaw controllers with a single lead network in which $\alpha = 30$ and $T = 0.5$. The controllers have a dead zone of ± 0.40 degree, a maximum angular velocity of 0.07 degree per second, and a maximum angular deviation of 0.37 degree. Preliminary characteristics of the second-stage roll controllers with $\alpha = 40$ and $T = 0.5$ are a ratio of jet-on time to period of jet actuation of 1:40, and a dead zone of 3 degrees. The maximum angular velocity during steady state is less than 2 degrees per second. Utilization of the same controller parameters for first-stage roll yields a dead zone of ± 3 degrees with a maximum error of less than 4 degrees.

Studies of the pitch-yaw engine deflection controllers for the first and second stages indicate that the transient response of the controllers would be improved by the addition of a lag network in the feedback loop. A stability study shows that the critical condition, from a controls viewpoint, exists in the region of maximum dynamic pressure.

A compatibility test of the TV-1 pitch-yaw amplifier with other circuit components is in process, and the breadboarding of the TV-2 pitch-yaw amplifier is complete. A subminiaturized electronic autopilot is in development as back-up for the TV-3 magnetic amplifier autopilot.

Arrangements have been made with the Bureau of Ordnance to study the effects of various thrust misalignments, spin rates, and unbalance on the spin stabilization of the third stage. This problem is being formulated for six degrees of freedom and will be programmed for solution on the digital computer NORC at the Naval Proving Ground, Dahlgren, Virginia.

Studies of the vehicle electrical system show that weight optimization may be realized by the use of batteries of equal capacity in the first and second stages. First-stage hydraulic power is to be supplied from a turbine takeoff; second-stage hydraulic power is to be supplied from a motor-driven pump.

Instrumentation

Telemetering

General - Tests have been conducted at WSPG to determine the mutual interference between the ppm/am, fm/fm, and pwm/fm telemetering systems. The results are as follows:

System	Separation for negligible interference
ppm/am on fm/fm	1.0 Mc
fm/fm on ppm/am	1.0 Mc
ppm/am on pwm/fm	4.0 Mc
pwm/fm on ppm/am	3.0 Mc

As a result of these tests the pwm/fm frequency requested from AFMTC was raised to 234.0 Mc.

Measurements have been completed by the New Mexico College of Agriculture and Mechanical Arts (NMCA&MA) on the three-element helix array antennas. The following results were obtained for frequencies of 216 Mc and 235 Mc:

	216 Mc	235 Mc
Gain	18 $\pm$0.5 db	20 $\pm$0.5 db
Beamwidth	$24^\circ \pm 1^\circ$	$19^\circ \pm 1^\circ$
Impedance	(51 $\pm$3) $\pm$j5	

Tests have been conducted also to compare the received signal at the Parker telemetering site with an eight-turn single-element helix, using a transmitter located at the USNOMTF telemetering lab. Results indicated that the three-element helix had a gain of at least 6 db over the one-element helix (13 db).

Two arrays were shipped to AFMTC on 9 March for release to RCA for inspection and operational test. The remaining four on present production are scheduled for completion by 1 April 1956. Further production for the island-chain stations will be authorized after satisfactory comment by RCA as to structural design and operation.

Schedules for the delivery and installation of telemetering equipment have been formulated by joint NRL-GLM action with the present firing schedules as criteria.

ppm/am Ground Stations - A trip to determine the status of the work being done by the Elsin Electronics Corporation revealed that the company was falling behind schedule. Under penalty of contract default, Elsin has increased the size of their working staff to a more adequate level. However, in order to assure meeting the first commitment, production of one ground station has been initiated at NRL for GLM plant checkout use in connection with TV-0.

ppm/am Transmitters - Bids for ppm/am transmitters are to be opened 20 March 1956.

ppm/am Calibrators - The manufacturer who was to supply the ppm/am calibrators has defaulted. An order for modification of four calibrators to meet requirements through TV-2 has been placed, and negotiations for a new contract have been initiated.

pwm/fm Transmitters - Bids for procurement of pwm/fm transmitters are due to be opened 20 March 1956. The packaging of transmitter components into single pressurized case is proceeding; the design is being pointed toward the ultimate use although the primary need is for TV-0.

The production history of ASCOP transmitters shows less than 10 kc variation in crystal frequencies and effects due to transmitter heating. A deviation of ± 30 kc appears optimum for operation and safe for maintaining the modulation within the passband of the 100-kc i-f amplifier.

pwm/fm Ground Station - ASCOP indicates that delivery of pwm/fm ground stations on schedule is expected.

Tests have been run at WSPG to evaluate the NEMS-Clarke 400 receiver. The results are as follows: When the 100-kc i-f amplifier was used an optimum deviation of ± 30 to ± 35 kc for minimum usable recording was found. The signal-to-noise ratio obtained with this deviation was 6 db better than that obtained with normal deviation and use of the 500-kc i-f amplifier.

fm/fm Transmitters - Specifications for fm/fm transmitters have been released for procurement initiation.

Services Contract - The NMCA&MA is submitting proposals for antenna work and for the furnishing of eight experienced telemetering men for a period of two years during firing operations. Approximately six men are being supplied by GLM for telemetering duty during the Vanguard operations. Personnel will be furnished by RCA for eventual operation of one ppm/am station at Cape Canaveral and the ppm/am station on Grand Bahama Island after a thorough training period; RCA has also granted installation space for these stations.

Procurement - Bids have been requested to provide tracking antenna mounts, ppm/am and pwm/fm transmitters, and an oscillographic recorder and processer. Four 28-foot Fruehauf trailers (to be modified) for launching vehicle telemetering ground stations have been procured through redistribution of surplus.

Range Instrumentation - Investigations have continued in the areas of range safety command equipments and electronic tracking equipment—primarily radars, beacons, and DOVAP equipment—for the purpose of establishing the applicability and availability of various items for Project Vanguard use.

Investigations concerning the status of presently available command receivers for use in the Vanguard launching vehicle have revealed that there is no equipment presently available to satisfy the requirements with respect to weight and electrical suitability. The following equipments were investigated: AN/DRW-6, AN/ARW-59, AN/ARW-67, R570 ARW and a receiver model presently under development by the Raymond Rosen Company.

Of all the receivers investigated, the AN/ARW-59 appears to be the most suitable from the standpoint of electrical characteristics and ability to withstand the rocket environment. The AN/DRW-6 receiver would be a second choice in this respect. The Collins Radio Company has been contacted concerning the development of a minimum-weight (less than 12 pounds) command receiver around the AN/ARW-59, and they will prepare a proposal for such a receiver. The Hoffman Laboratories were also informed of the requirements and are preparing a proposal based on the AN/DRW-6.

A request for six AN/ARW-59 receivers and KY-55/ARW decoders for use in TV-0, TV-1, and TV-2 has been sent to the Bureau of Aeronautics.

Electronic Tracking - An official request has been made to the Bureau of Aeronautics for the AN/FPS-16(XN-1) radar and a request for an (XN-2) model is being prepared for submission to the Army. Discussions have been held with range instrumentation personnel at NAMTC, Point Mugu, in which the radar requirements for Project Vanguard were outlined and the official request for the AN/FPS-16(XN-1) was reviewed.

A request has been made for RCA to submit a proposal for the modification of the AN/FPS-16(XN-1) radar range unit and data pickoff. This modification will consist of extending the radar range to 300 miles and providing tracking rates of 8000 yd/sec. In addition, digital data pickoffs will be incorporated.

A request for three AN/DPW-1 radar beacons and beacon antennas has been made to WSPG.

Modifications made by the Lockheed Aircraft Company to the AN/DPN-19 radar beacon to enable it to withstand the environmental conditions of solid-propellant rockets have been investigated. These modifications result in an improvement and a corresponding increase in available transmitter power output. Structural and electrical modifications were made for improvement of reliability.

Present DOVAP film recording techniques are not adequate for the velocities to be encountered in the Vanguard second and third stages. The Ballistics Research Laboratory has developed magnetic tape recording methods for DOVAP which may be used; this information has been forwarded to AFMTC.

Antennas

A design specification (NRL 4100-2) for Vanguard vehicle antennas has been completed and forwarded to GLM.

The Physical Sciences Laboratory of the New Mexico College of Agriculture and Mechanical Arts has developed a cutoff "quadraloop" antenna. Possible further development with an array of these "quadraloop" elements spaced around the circumference of the rocket body is being investigated.

Minitrack for Third-Stage Test Vehicle Tracking

The use of Minitrack for determining the velocity vector for the third stages of TV's 3, 4, and 5 is being considered. Two or three ground stations are proposed on the down-chain islands.

THE SATELLITE

Configuration and Design

Design is now proceeding on three types of satellite:

(1) A minimum-weight satellite containing only Minitrack equipment—The size and shape would be consistent with the equipment and weight requirements. From a weight standpoint, it would be preferable to attach the sphere solidly to the third-stage shell and omit spin-isolation bearings and separating devices. The temperature and acceleration effects on the structure and equipment are being investigated. The weight of this satellite might be as little as eight pounds; it would not be more than eleven pounds.

(2) A 20-inch spherical satellite weighing 21.5 pounds—It would contain a Minitrack and telemetering transmitter; temperature, pressure, and erosion gauges; and equipment for the measurement of variations in solar Lyman-alpha radiation. It would be mounted on a bearing to reduce the spin rate, and a separating mechanism would cause the satellite to leave the third-stage case at about five feet per second after burnout.

(3) A satellite which would contain the same instrumentation as (2), but might remain attached to the third-stage case and would have an optimum configuration which has not yet been established.

The final choice of the satellite type will be made at a future date.

A study is being made to fabrication methods for final satellite assemblies. At present, the most promising method seems to be a modular assembly of the type developed in Project Tinkertoy. This method appears to offer great flexibility in combining a few standard subassemblies to meet a wide variety of needs for individual satellites. In addition, it provides a sturdy mechanical assembly with a weight advantage due to the common structure and encapsulation medium for such items as transistors, resistors, capacitors, etc.

Environmental Tests

For the purpose of emissivity studies, one four-inch aluminum sphere has been coated with 3μ of silicon monoxide, and several others have been coated with Alzak; the latter, however, turned out poorly, and another batch is being coated. Equipment for the emissivity studies has been completed and it is anticipated that data will be available in the near future. The equipment for the reflectance studies also has been completed.

A sample of PV 101, the best Air Force "temperature white resistant" paint, has been obtained from the Vita Var Corporation. This paint will be investigated as a possible means of attaining the desired satellite visibility under the anticipated temperature conditions.

The Naval Research Laboratory will subject each completed satellite to environmental conditions simulating actual flight conditions as nearly as possible. The environmental extremes which a satellite and its instrumentation will encounter have been estimated. The simulation tests described in Appendix A are being developed to insure, insofar as possible, that the designs of the instruments and the structures of the satellite are functional under flight conditions. These test conditions are necessarily tentative and will be superseded as more definitive information becomes available.

Instrumentation and Tracking

The following schedule for the development of scientific instrumentation for the first satellites has been agreed upon by the various instrumentation groups:

1. Design information to be available by 1 May 1956

2. Breadboard models of electronic equipment to be delivered for compatibility tests by 1 July 1956

3. Design of scientific instrumentation to be firm by 15 September 1956

4. Subcontracted components to be delivered by 1 December 1956

5. Final assemblies of prototype units of instrumentation to be ready for tests by 1 January 1957

6. Working models to be delivered by 1 February 1956

7. Units to be worked into satellite design after February 1957

8. Spare units to be delivered during February and March 1957

Minitrack

Preparations have been completed for a technical representative to go with the site survey team to inspect Minitrack sites in Panama, Quito, Antofagasta, Santiago, and Havana. A survey receiver has been completed and will be used by the group to check on 108-Mc interference.

Another technical representative is now on a trip to Eleuthera, San Salvador, Mayaguana, Grand Turk, and Antigua, for the purpose of surveying sites for Minitrack stations. The stations on several of the first four islands will be used for third-stage test vehicle measurements, and the Antigua station for measurements of the mission flights.

Four 28-foot Fruehauf trailers for Minitrack stations (in addition to the four acquired for launching vehicle telemetering ground stations) have been procured through redistribution of surplus.

Antennas

The satellite antennas are an important design consideration affecting shell design and installation in the launching vehicle. Two general types are being considered at this time—a telescoping powder-actuated antenna, and a spring-actuated antenna which might consist of several spring tapes or might be a lightweight rod mounted on a spring. The choice of the antenna type to be used will be based on an evaluation of all types; this evaluation is expected in about a month.

Telemetry

A telemetry coding system for modulating the satellite transmitter with the desired environmental and scientific information is being studied. Three systems are being

considered which differ in detail but use the same basic principles. In general, these systems use a square-hysteresis-loop magnetic core material to provide a pulse-time-modulated telemetry system. Switching transistors are used to apply various bits of input data selectively to the core windings, with the time required for the core to pass from saturation in one direction to saturation in the opposite direction being an inverse function of the applied signal. Current plans are to provide a telemetry system of approximately ten channels to be sampled in sequence, this sequence to be repeated throughout the interrogation interval.

The systems of coding transducer information and channeling it to the transmitter are basically both frequency sharing and time sharing. Since frequency sharing imposes wide bandwidth requirements along with the chance of intermodulation, and time sharing requires a separate gate or commutation period for each channel, these systems combine the two principles, thereby conserving weight and bandwidth.

The modulation envelope or signal fed to the transmitter would be an audio signal in the range of two to eight kc modulated with a square wave whose period would vary between 10 and 100 millisecond. A typical demodulated signal recorded at the ground station might be as shown in Fig. 3. The first channel is represented by the frequency A; the second channel is the length of time the frequency A is on; the third channel is the length of time between A and D; the fourth channel is represented by the frequency of D; and so on. The illustrated waveform supplies twelve information channels, one of which would monitor battery voltage and also serve as a reference key by being either longer or shorter than any other interval. The bandwidth is 8 kc with signal frequency components held between 1 kc and 9 kc.

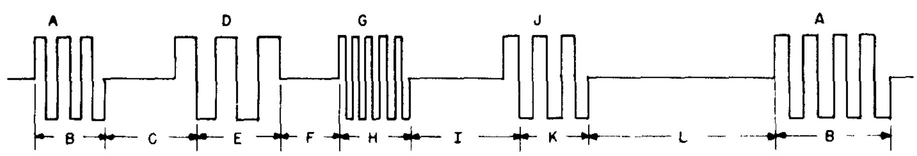

Fig. 3 - A typical demodulated signal

The three systems are being studied with the hope combining the best features of each in the ultimate telemetry system. The originally contemplated "ring" type system has been abandoned since the failure of one channel would open the ring and interrupt the sequence. The three systems have all been in laboratory operation and a choice will be made on the basis of the best compromise between system weight and transmission of maximum intelligence in the event of failure in any component or channel.

Peak-Current Storage Circuit

A circuit is being developed, primarily for the Lyman-alpha experiment, for storage of the peak orbital output of a photon counter for subsequent readout during the interrogation interval. This circuit is predicated upon the seldom-used property of torroidal cores wherein the flux level changes by a fixed amount when a given value of unidirectional current is applied to the windings. The flux level will then remain at this value even though the magnetizing current is removed, and subsequent currents smaller than that originally impressed will not change the flux level. However, if a current pulse of greater

amplitude than the original is applied, the flux will change to a new corresponding level. The flux level in the core will be read out during the interrogation interval to provide information regarding the peak value of current in the winding, and thus the peak value of Lyman-alpha during one satellite orbit. No deterioration of stored information was detected with an eighteen-hour delay between storage and readout. The transfer characteristics are somewhat sensitive to temperature but flux level for a given current appears to vary linearly with temperature over the range of -70°C to +100°C and since the temperatures will be known from environmental experiments the appropriate correction can be made.

Voltage-Integrating Magnetic Memory

The use of properties of torroidal magnetic cores for voltage integration is similar to the use just described, except that in this case the applied signal consists of voltage pulses of fixed magnitude and duration and the core flux level at readout corresponds to the integral of e dt and is thus proportional to the number of such pulses applied. Originally this storage unit was planned for storage of cosmic-ray rigidity experiment data and meteor collision detection. Current information indicates that the rigidity experiment will not be performed and application is being directed toward needs of the meteor collision experiment. Two types of circuits are being studied. In one, up to approximately two hundred "counts" can be stored and read out during the interrogation interval. The other circuit will store up to approximately sixty "counts" and then automatically reset, advancing a succeeding core one "count." Cascading counters of the first type as a last stage with any desired number of the second type will provide any necessary storage capacity, and readout of all cascaded circuits during interrogation would provide accuracy of 2 percent or better for a high dynamic range.

Magnetic Memory Readout

Flux-level readout of cores used for storage of peak or integrated counts is most readily accomplished by using the core in the telemetering circuits of the first section. This procedure does, however, destroy the stored information on the first readout and would provide on each subsequent channel position only the short-term output values that would be stored after the immediately preceding readout. To avoid this difficulty, which would result in loss of information due to noise or low signal strength at the start of an interrogation interval, nondestructive readout methods are being devised to retain the stored information with negligible deterioration during the interrogation interval. Cores would be reset for start of a new orbit by the relay which terminates the interrogation transmission.

Meteor Collision Detector

The equipment for detecting meteor collisions will consist of a sensitive electromechanical transducer to sense the collisions, a transistor amplifier, and a pulse standardization circuit to supply appropriate fixed "counts" to the voltage-integrating magnetic memory described above. A laboratory breadboard model of the transistor amplifier has been made and tested and a 20-inch aluminum sphere is being fabricated for experiments on transducer sensitivity, resonant frequency, placement, etc.

Data Recording System

Initial thinking and study on the problem of data recording has led to the choice of magnetic tape as the recording medium at the interrogation sites, with a central transfer

system at NRL to reproduce the recorded information on photographic records for final use of the various experimenters in data reduction. Vague consideration has been given to the possibility of using the NAREC computer for direct processing of data if the volume of data and demands of experimenters make such automatization necessary.

Visual Acquisition

Army Ordnance has located several hundred Elbow telescopes which may be of use for visual acquisition purposes. The possibility of obtaining funds to contract visual acquisition work to universities is being considered.

DATA PROCESSING

The requirements for the satellite orbit computational facilities, as described in Project Vanguard Report No. 2, were sent to several possible contractors by the Office of Naval Research on 9 March 1956. A meeting will be held on 29 March 1956 at ONR by representatives of NRL and ONR to discuss the details of these requirements for the information of the companies interested. Proposals are to be submitted so that they will be received by ONR no later than 15 April 1956. As soon as these proposals have been received, a decision will be made regarding a contractor for these facilities.

* * *

APPENDIX A
Tentative Description of Satellite Environmental Simulation Tests

Vibration Environment

Predictions of Vanguard satellite vibrations during powered flight are necessarily based on the limited amount of data available from tests of other rockets in the past. The predictions are believed to be somewhat conservative and will be revised as data is obtained from static firings and flights of Vanguard rockets.

There is a good chance that pressure oscillations of one or more of the motors will subject the satellite to steady-state sinusoidal vibrations. Accordingly it is planned to test all satellite components by attaching them to a vibration table which has 8-g zero-to-peak sinusoidal acceleration. The frequency of vibration will be increased smoothly from 20 cps to 2000 cps in such a manner that 10 minutes of vibration occurs in the range 20 to 500 cps, 10 minutes in the range 500 to 1000 cps, and 10 minutes in the range 1000 to 2000 cps. The components will be subjected to motion in three mutually perpendicular directions so that the total test time will be 1-1/2 hours.

The satellite will also be subject to random vibrations due to aerodynamic forces and random pressure pulses in the motors; this vibration is mathematically identical to electrical or acoustic "white noise", in that a group of randomly selected values of acceleration will have a Gaussian distribution. The test to which satellite equipment will be subjected is a random vibration with a uniform spectral density in the range 20 to 2000 cps with substantially zero value outside this range. The spectral density level will be 0.2 g^2/cps which means that the root-mean-square acceleration of the table will be 20 g. This test will be run for 5 minutes in each of three mutually perpendicular directions.

The satellite will be subject to other accelerations such as thrust, shock due to motor starting and separation of stages, and centrifugal accelerations. It is expected that these will impose less severe conditions than the two vibration conditions already described. However, in order to be conservative, a centrifuge test at 50-g acceleration in the direction of flight acceleration will also be conducted.

Facilities are being set up at NRL for subjecting satellite components to the above vibration tests. Since the validity of a test increases with the amount of realistic structure which is interposed between the vibration table and the component under test, it is preferable to test assemblies rather than single components. However, components can be given provisional tests by themselves to indicate where weak spots might show up in later tests of assemblies.

It is not practical in most cases to attempt design calculation of stresses due to vibration because one must calculate modes of vibration and estimate the damping which determines the resonant amplification of table motion. Accordingly in design one can only follow principles which have been found by experience to produce vibration-resistant assemblies. Experienced designers of missile electronic components have cited examples

of successful design practices.* The basic procedure is to stiffen chassis and attachments of parts so that resonant frequencies of the assembly are very high. This tends to eliminate resonant buildup of chassis vibration, amplitudes which might produce damage to resonant elements of tubes, etc. This stiffening also reduces relative motions of chassis parts so that wires are subject to less flexing.

Temperature and Pressure Environment

The satellite sphere will be placed in a vacuum chamber and subjected to pressures from 760 to 10^{-2} mm Hg. At the lower pressure, the satellite will be rotated at 2 cycles per second and subjected to 1-1/2-hour temperature cycles with the shell temperature oscillating between +40°C and -20 °C for a two-week period. During this period the satellite will be challenged and monitored a number of times each day. All instrumentation and pressure seals will be functional during this period and internal instrument compartment temperatures and pressures will be monitored.

The pressure environment would be changed by a meteor penetration of the sphere. This will be simulated by releasing the gas from the sphere into the vacuum chamber. All instrumentation must be functional after this test.

It is presently estimated that the shell temperature fluctuations will probably range between +40°C and -20°C or -30°C. It is also estimated that the central payload cylinder will experience temperature excursions within the range +40°C to 0 °C. It is not possible at this time to provide better estimates – the uncertainties involved are too great.

The estimates above were made assuming a gross satellite weight of 21 lbs, a magnesium shell 0.015 inches thick and 20 inches in diameter, and a specific heat of 0.2 cal/gram-°C. The outside of the satellite shell was assumed to have an absorptivity of 0.2 for solar radiation and an effective absorptivity of 0.14 for long wavelength radiation. Under these conditions the mean temperature about which the satellite components fluctuate is +20°C. A grey body has a mean temperature of about 0°C.

The estimated excursions were arrived at by assuming good radiative coupling only between the shell and the internal cylinder. Conduction and convective processes can be expected to provide more effective thermal coupling which will reduce the shell excursions to some extent. The resultant payload excursions, however, should still fall within the broad limits stated above.

An unpleasant feature is the required tight control of the effective absorptivity values. For example, differences of ±10 percent in the desired visible infrared absorptivity ratio change the orbital mean temperature from +20°C to +25°C and +14°C respectively. Because of this, and because it will be necessary to adjust this absorptivity ratio to a predetermined value for the satellite shell, there is under construction a concentric-sphere calorimeter for the determination of the long-wavelength spherical emissivity of visibly-transparent infrared-opaque coatings on polished metal surfaces. It is expected that the coating found most desirable will be used to modify the radiation properties of part of the area of the external satellite shell in order to achieve the desired absorptivity ratio.

Aerodynamic heating during powered flight has not yet been adequately estimated for determining the temperatures of the satellite.

*"Environmental Design of Electronic Equipment," C.I.T. Jet Propulsion Lab. Prog. Rept. 20-249 (Confidential), February 7, 1955

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Naval Research Laboratory. Report 4728 [CONFIDENTIAL] PROJECT VANGUARD REPORT No. 3 - PROGRESS THROUGH MARCH 15, 1956 [Unclassified Title], by Project Vanguard Staff. 20 pp. & figs., March 29, 1956.

A preliminary support and data acquisition plan for Project Vanguard has been prepared by AFMTC, and a completed plan for the test program is expected in the near future. The Minitrack station originally planned for Barbuda will be considered as a part of the range instrumentation facilities. However, a scheduled site survey trip to Antigua is expected to result in the location of the station on that island rather than Barbuda for logistic reasons. Minitrack equipment may also be installed on two regular range stations in the island chain.

Reduction of the third-stage length to 60 inches has reduced the over-all length of the launching vehicle to 71 feet 4 inches, and substitution of magnesium alloy for aluminum alloy in certain areas has reduced the weight of the vehicle by 39 pounds in the first stage and 14 pounds in the second stage. A stainless steel "spaghetti" chamber for the second stage is being fabricated, and a program has been initiated for a similar aluminum chamber which, if satisfactory, will result in a substantial weight saving. A new subsonic wind-tunnel test will be made on the Vanguard configuration.

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1. Satellite vehicles - Launching
2. Satellite vehicles - Research
3. Rockets - Development

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Schedules for delivery and installation of launching vehicle telemetering equipment have been formulated. Development of ppm/am ground stations is behind schedule and the contractor's staff has been increased in order to meet the schedule. Specifications for fm/fm transmitters have been released for procurement initiation, and bids for ppm/am and pwm/fm transmitters have been received. Proposals have been requested from several contractors for a minimum-weight command receiver for the launching vehicle.

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